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The application of Discrete Event Simulation (DES) to enhance wait times and space utilization of a Multi-department Clinic

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Abstract – There has been an increasing demand for outpatient services that support patient experience and quality of care. Consequently, healthcare systems aspire to reduce operational costs and improve resource utilization through different strategies. Given the complexity of multi-department outpatient healthcare facility operations, DES has been recognized as an effective tool for evaluating performance outcomes and design decisions. The purpose of this study was to introduce Discrete Event Simulation (DES) as an effective tool in the architecture planning of a multi-department outpatient clinic. The DES integrated patient flow, schedules, proposed layout, and staffing information to identify space and staff utilization, wait for the provider (WFP), and wait for the room (WFR). The study explored the effects of pooling decentralized registration desks into a centralized desk and staffing with additional kiosks for the primary care departments. We also converted underutilized exam rooms into telehealth rooms, flexible consult-exam rooms, and dedicated pediatric waiting areas. registration pooling and kiosks improved staff resource utilization. Allocating additional providers and exam rooms to departments reduced their WFP and WFR. DES indicated minimal operational effects of transitioning underutilized exam rooms to alternate functions. This finding enabled us to determine if space allocation modifications negatively affected operations. The findings suggest the effectiveness of DES in analyzing the impact of alternative design strategies on operational outcomes through a data-driven approach. This understanding is valuable, as improved resource allocation and streamlined operation are associated with cost reduction and enhanced patient and staff satisfaction.

Keywords: *capacity planning, clinic design, discrete event simulation modeling, healthcare design, predictive modeling.*

I. INTRODUCTION

Over the past decade, there has been an increasing demand in the United States (US) Healthcare system to provide access to low-cost, efficient, high-quality care (Wennberg et al., 2008). In 2021, the US spent twice as much as comparable countries on health impacted by costly hospital and physician payments (OECD Health Statistics, 2023). Accordingly, the patient's health condition impacts the decision to receive inpatient or outpatient care. Inpatient care facilities are hospitals or similar buildings where patients are admitted to a designated room for dedicated medical care or observation (Torres, 2022). Patients in inpatient facilities usually have severe conditions or recover from life-treating injuries. Examples of inpatient care include childbirth, complex surgeries, and serious health issues requiring constant monitoring o healthcare professionals (Torres, 2022).

In contrast, an outpatient facility is a medical office or location where patients are not admitted or stay overnight for medical, dental, or other services (Centers for Medicare and Medicaid Services, 2022; Hong et al., 2013). According to a 2019 Health Care Cost Institute study, outpatient services increased from 11.1% in 2009 to 12.9% from 2009 to 2017, respectively (Hargraves & Reiff, 2019). Moreover, health insurance reimbursements impacted this trend by offering more desirable payment procedures for outpatient services (Culver et al., 2022; Medpac, 2019). This reimbursement shift decreased hospital revenues, increased overhead and labor expenses, and reduced inpatient days (Hargraves & Reiff, 2019; Medpac, 2019). It also encouraged hospitals to acquire market share and earn outpatient facilities and physician offices (Medpac, 2019).

The growth in outpatient services is also attributed to the expansion of technologies such as remote monitoring, wearable devices, and mobile health applications, internet-based consults that improved patient monitoring and continuity of care for chronic conditions (American Medical Association, 2020; Brotman & Kotloff, 2021; Greiwe, 2022; Patel et al., 2021; Wosik et al., 2020). Telehealth is described as providing a complete spectrum of care at a distance without direct physical contact between patients, providers, or care coordinators using tools and technology (American Medical Association, 2020; Wosik et al., 2020).

Telemedicine is described as providing care remotely to patients and is a subset of telehealth that is advantageous for disease management, follow-up care, and frequent monitoring (American Medical Association, 2020; Greiwe, 2022). The growth in Telehealth technology for healthcare visits was exceptionally prevalent in response to the coronavirus disease 2019 (COVID-19) pandemic to reduce patient volume and in-person visits (Betancourt et al., 2020; Greiwe, 2022; Patel et al., 2021). For example, the study by Patel et al. (2021) found that 30.1 percent of total outpatient visits were provided via telemedicine during the pandemic. Further, they found that the weekly telemedicine visits increased twenty-three-fold compared with the pre-pandemic period.

In addition to employing telehealth as a promising tool to improve access to care, the increased outpatient volume has increased pressure to enhance operations, costs, and resource utilization through different strategies, including resource pooling (Hong et al., 2013; Vahdat et al., 2019). Pooling is one of the most prevalent strategies in outpatient clinics to streamline processes, reduce waiting time, and improve patient and staff satisfaction through resources (al Hroub et al., 2019; Ciulla et al., 2018; Norouzzadeh et al., 2015; Vahdat et al., 2018; Vanberkel et al., 2012).

The planning, design, and construction of multi-department outpatient healthcare facilities are complicated, expensive, and complicated (al Hroub et al., 2019; Suhaimi et al., 2018; Vahdat et al., 2019). These facilities include multiple stakeholder processes, including physicians, nurses, nurse assistants, and patients (Hong et al., 2013; Suhaimi et al., 2018; Vahdat et al., 2019; Vázquez-Serrano et al., 2021). Further, appointment types, availability of resources, and patient arrival times impact the outpatient delivery systems (Suhaimi et al., 2018; Vahdat et al., 2019). Therefore, having a logical decision-making process to achieve efficient outcomes, such as improved waiting time or resource utilization, may be challenging in these settings (Suhaimi et al., 2018; Vahdat et al., 2019).

Given the complexity of mulita-department outpatient healthcare facility operations, Discrete Event simulation (DES) is considered an effective tool for evaluating resource pooling, performance outcomes, resource utilization, capacity planning, and turnaround times across different situations (al Hroub et al., 2019; Hong et al., 2013; Vahdat et al., 2018, 2019; Vanberkel et al., 2012; Vázquez-Serrano et al., 2021). Through the DES evaluation, the design strategies for multi-department clinic design are integrated with critical components of operations to achieve higher-quality patient-centered care outcomes (Cai & Jia, 2019; Vahdat et al., 2018).

DES, a time-to-event model, has been applied in healthcare research from 1981 onwards to improve healthcare systems and operations by evaluating effective resource utilization (Chahal et al., 2013; Mielczarek & Uziałko-Mydlikowska, 2012; Swain, 2011). Applications include reengineering patient flow for reduced waiting time or improving staff scheduling (Mielczarek & Uziałko-Mydlikowska, 2012; Suhaimi et al., 2018; Swain, 2011; Vahdat et al., 2018, 2019). Additionally, some models attempt to optimize planning resources by making a future forecast for the quantity, deficiency, or efficient adjacency of architectural spaces (Hong et al., 2013; Mielczarek & Uziałko-Mydlikowska, 2012; Suhaimi et al., 2018; Vahdat et al., 2018, 2019; Zamani, 2022). Data entry includes the patient

flow patterns, staff activities, number of fundamental rooms, patient acuity, the activities performed, and performance (Hong et al., 2013; Suhaimi et al., 2018; Vázquez-Serrano et al., 2021; Zamani, 2022).

Resource allocation is a popular application for simulation modeling of simulation modeling is to determine appropriate staffing levels (Santibáñez et al., 2009; Vahdat et al., 2018; Vanberkel et al., 2012; Wischik et al., 2008). Another practical usage of DES is to evaluate the impact of planning and volume changes on the future capacity requirement, efficient design, and staffing needs on operational outcomes (Cai & Jia, 2019; Mielczarek & Uziałko-Mydlikowska, 2012; Rohleder et al., 2007; Santibáñez et al., 2009; Swain, 2011; Vahdat et al., 2019; Zamani, 2022; Zeigler et al., 2000).

For example, Santibáñez et al. (2009) analyzed the impact of operations, scheduling, and resource allocation on patient wait time, clinic overtime, and resource utilization in a multi-provider ambulatory care unit. The simulation scenario suggested pod configuration and pooling exam rooms across physicians reduce the number of needed exam rooms by 22.3%. Through the application of DES, Zamani's (2022) study proposed and addition of a results-pending room for a future Emergency Department (ED) layout that potentially reduced the admitted patient's Length of stay (LOS) by 32%.

The study by Rohleder et al. (2007) indicated that consolidation from 25 to 18 patient service centers of smaller establishments into larger establishments improves resource utilization and maintains patient waiting times to less than 20 minutes. Suhaimi et al. (2018)employed DES to explore the effects of Mid-level physician (MPL) resource sharing between physicians across two outpatient centers. Findings showed a 6% improvement in the waiting time in the room and a 4% reduction in LOS. The study by Cai and Jia (2019) describes the application of the simulation model for the early design office of a family medicine center (FMC) clinic to evaluate the number of exam rooms according to different patient volume scenarios. Findings showed that even under peak volumes, 25% of the exam rooms would not be utilized.

In essence, DES is an effective decision-making tool for outpatient clinic organizations, designers, and planners for informing the critical design and planning decisions such as space needs, adjacency requisites, or projected space utilization outcomes(Cai & Jia, 2019; Suhaimi et al., 2018; Vahdat et al., 2018, 2019; Vázquez-Serrano et al., 2021). Each facility has unique design constraints and characteristics that need to consider patient flows (Vahdat et al., 2019). Nevertheless, a limited number of studies employed DES during outpatient clinic consolidation planning to explore the impacts of space allocation strategies on future operational outcomes (Cai & Jia, 2019; Hong et al., 2013; Vahdat et al., 2019).

This study aims to add to the body of literature by describing the implementation of DES in supporting healthcare design and planning decisions. The project was an outpatient facility in Columbus, Indiana that aimed to consolidate various clinical specialties. Each specialty dealt with different appointment schedules, patient types, appointment lengths, and staffing models. The planning team had proposed a certain number of exam rooms per clinical specialty based on current planning formulas and metrics. Later, the researcher was involved in investigating how the future design of this facility supports operational outcomes using DES and creating a detailed development of the model through historical data.

The research had four fundamental questions aligned with the client's goals: (1) Does the proposed new design and staffing provide enough capacity for future patient volumes? (Current state of the model) (2) How can centralized registration systems for departments in combination with check-in kiosks impact staff and operational outcomes? (3) Given the current patient volume, can some space functions be altered for improved utilization and flexibility? (4) Which departments may need additional providers during maximum patient volume?

II. METHOD

A. The Setting

This paper describes the application of DES for a case study for the adaptive reuse of a mall reimagined as a "one-stop-shop" of health, wellness, and activity facilities, including an ambulatory care center and offices. Planning and Design teams strived to integrate architectural precedents for innovative approaches that improve health, wellness, and optimum operational outputs. The city and the healthcare

system's dual ownership of the project created a synergic partnership for improved health through a new wellness and recreation campus of approximately 400,000 square feet (SF).

To achieve patient-centered outcomes, planners sought to enhance wayfinding experiences and convenient parking access for acute or chronic illness patients. Designing a public "concourse" was a patient-centered innovation approach that aimed to improve wayfinding, visibility, patient engagement, and flexibility for future adaptation. The proposed clinic comprised eleven modules consolidated in the shared new facility of approximately 120,000 SF. The pod-based on-stage-off-stage departmental layouts aimed to increase face-to-face communication and team dynamics.

Figure 1 displays the overall layout of the multi-department clinic, with each department represented in a different color. The multi-department clinic included twelve departments: primary care (PC), neurology, Obstetrician-Gynecologists (OB-GYN), VIM care, audiology, pediatrics, laboratory, and Occupational therapy-physical therapy (PT-OT). This DES interface supported creating a complex multi-department layout linked to the patient flow, as shown in Figure 2. For this study, we will only report the current and proposed state of the primary care and pediatrics departments.

Fig. 1. The current proposed layout for the multi-department clinic
Source: Author (2023)

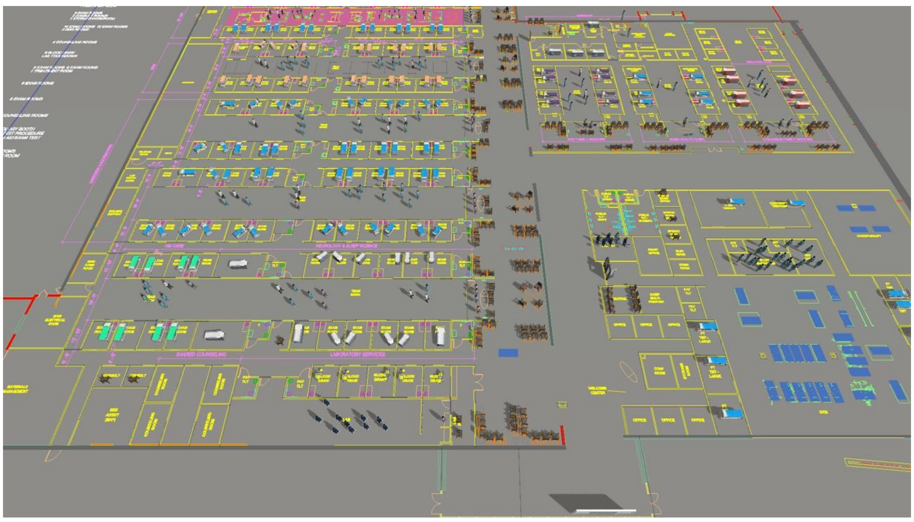

Fig. 2. An overview of the visual interface of the FlexSIM simulation that improved communication across stakeholders
Source: Author (2023)

B. Data Collection and Analysis

The study methods included the application of DES for quantitative evaluations of the impact of space allocation, resource pooling, and planning decisions on operational outcomes. These include waiting times, exam room utilization, staff utilization, and patients' LOS. The research team also gathered qualitative information through interviews with clinicians and administrators for model validation, department culture for technological adaptation, and realistic implementation of suggestive DES scenarios.

Fundamental elements of DES in healthcare include patient flows through the system, arrival rates, location resources, equipment resources, staffing resources, and service time (Cai & Jia, 2019). For this project, the arrival rates were extracted from historical Electronic Medical Record (EMR) data from July 2020 to June 2021 from more than 170,000 appointments (n = 176,286). It is noteworthy that the database for department flow and the schedule was based on COVID patient flow and resources. Thus, the patient flow may fluctuate or increase in the future, which was a limitation of this study. Nevertheless, the focus of this study is not to understand or evaluate scheduling or patient arrival improvement but rather to understand, by controlling the existing processes and scheduling conditions, how specific design or staffing changes impact potential outcomes, such as patient waiting time.

The patient data included the date, time, expected appointment length, department type, patient arrival time, check-in, wait for the exam room (WFR), rooming time, check-out time, wait for the provider (WFP), time with the provider, and check-in to check-out duration. Diagnostic codes and department types categorized patient visits. Due to the wide variety of the data and existing outliers, multiple verification sessions were performed with the clinicians. We excluded incomplete appointments and outliers from the calculations.

Resource data were based on the proposed clinic floor plan, staffing schedule, and equipment record. Performance measures included waiting for provider, registration, staff utilization, milestone-to-milestone durations, room utilization rate, or waiting for an exam room. Process mapping of the patient flow per department was created to validate and communicate the DES logic to stakeholders. Administrative and clinical staff per department verified that process logic connected all the model elements.

Based on the historical data, the clinic's operating hours ranged from 6:00 AM to 6:00 PM. The primary care (PC) departments included six clinics with different patient volumes and distribution types. The maximum patient counts per day differed per department and impacted the designated number of exam rooms (Table 1). The distribution of patients arriving per hour for each department varied per department and was accounted for in the DES model. Table 2 shows the pediatric department's MA and MD staffing resources.

Table 1. Percentage of patient arrival per hour for the primary care and pediatrics department.

Hours	**Departments**						
	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	Pediatrics
6 AM	0%	1%	0%	1%	0%	1%	0%
7 AM	3%	12%	10%	5%	7%	4%	3%
8 AM	16%	18%	13%	17%	15%	12%	10%
9 AM	17%	17%	13%	20%	15%	14%	11%
10 AM	16%	16%	12%	14%	16%	14%	12%
11 AM	5%	6%	7%	12%	6%	9%	6%
12 PM	5%	6%	5%	3%	6%	6%	4%
1 PM	15%	12%	15%	2%	12%	12%	15%
2 PM	11%	8%	12%	10%	11%	11%	14%
3 PM	11%	3%	11%	11%	10%	11%	15%
4 PM	2%	0%	2%	4%	2%	6%	12%
5 PM	0%	0%	0%	1%	0%	0%	0.08%
Grand Total	100%	100%	100%	100%	100%	100%	100%

Table 2. Example of the pediatric department's staffing schedule.

Role	**Start Time**	**Stop Time**	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
MA	8:00	17:00		x	9a-5p	x	
MA	7:42	17:00	x			x	
MA	7:42	17:00	x	x	x		x
MA	7:18	17:00	x	x	x	x	x
MA	8:00	17:00	x	x	x	x	x
MA	7:42	17:00	x	x	x	x	x
MA	7:42	17:00	x	x	x	x	x
MA	7:42	17:00	x	x	x	x	x
Provider	8:00	17:00		x	x	x	
Provider	7:42	17:00	x			x	
Provider	7:42	17:00	x	x	x		x
Provider	7:18	17:00	x	x	x	x	x
Provider	8:00	17:00	x	x	x	x	x
Provider	7:42	17:00	x	x	x	x	x
Provider	7:42	17:00	x	x	x	x	x
Provider	7:42	17:00	x	x	x	x	x

The EMR contained information on patient types and maximum appointment lengths. Table 3 displays an example of patient type variation for PC 3 and PC 5, and PC 6 departments. Each appointment type had a unique triangular distribution accounted for in the model. Table 4 illustrates an example of appointment-type descriptive statistics for the PC 4 department.

Table 3. Examples of different patient types for three of the PC departments are accounted for in the model.

	PC 3		PC 5		PC 6	
Row Labels	% of patients	N	% of patients	N	% of patients	N
Botox	1%	94				
Counseling					7%	1177
Hospital F/U	3%	447	0%	7	2%	353
Med Well	3%	494	3%	199	4%	677
New Patient	7%	1075	8%	634	8%	1437
Newborn						
Nurse Visit	13%	2055	5%	348	8%	1533
Office Visit	48%	7898	70%	5292	28%	5190
OV Ext	3%	569	1%	50	12%	2213
OV OB					2%	443
physician	8%	1281	5%	377	7%	1361
Procedure					1%	144
Resp 15	5%	853			7%	1337
Resp 30	1%	214			3%	611
Telehealth New patient	1%	115	0%	4	0%	8
Telehealth	7%	1151	9%	649	3%	593
Well Child			0%	7	8%	1434
Grand Total	100%	16246	100%	7567	100%	18511

Table 4. Descriptive Statistics of appointment types for the PC4 department.

	Appt Len				
	New Patient	**Nurse Visit**	**Office Visit**	**Well Child**	**Physician**
Valid	113	937	2635	31	643
Mean	41.283	15.032	19.617	29.516	39.051
Std. Deviation	6.505	0.693	7.144	2.694	7.438
Minimum	30	15	15	15	15
Maximum	45	30	45	30	60

C. The Current State DES Model

DES was built in the FlexSIM 2021 software using the EMR data analysis linked to the proposed multi-department layout. The FlexSIM software compiles patient flow, scheduling, resources, and floor

plan information to generate different outputs of interest, such as space utilization, staff utilization, and patient wait times for rooms, providers, or being registered. The resulting outputs were exported into an excel format for statistical analysis in the JASP 0.16.4 software. The DES model development was an iterative process involving construction, collecting feedback from involved clinicians and management, and incorporating the insight into the model. The base model outputs were validated and verified with real-world data and clinician inputs. The simulation scenarios were tested by altering some parameters of interest to understand optimal resource numbers and room utilization rates that can inform design and planning decisions.

The model included all staffing resources and suggested schedules per department. Patient types impacted appointment length; therefore, its distribution was accounted for in creating the patient flow per department. The study made several assumptions during the model development for all simulation models. Firstly, the patient arrival patterns captured the maximum patient arrival per day and daily distribution pattern provided by the EMR information. Secondly, it was assumed that the clinical operations continued until all scheduled patients left the building, and afterward, all locations and resources were reset. Thus, the simulation model did not include a warm-up period.

Consistent with (Vahdat et al., 2018), the current model assumes that MAs and LPNs per department work are a shared resource pooled between MDs and exam rooms. Additionally, the model assumed that clinicians see and prioritize patients based on arrival time at the clinic. Figure 3 displays the patient's steps for the primary care and pediatrics departments. Initially, patients enter the building from the main entry point and walk toward the concourse and the department of interest. Patients stop at the registration desk to complete or check in and await their appointment. Afterward, a medical assistant (MA), or a licensed practical nurse (LPN), escorts the patient to an exam room. The clinic's historical data identifies this period as the "room time," in which the MA or LPN collects vitals and necessary information and reports the results to the Electronic Medical record (EMR) and physician.

Patients remain in the exam room until the physician is available and enters the exam room (described as the time with the provider). In addition to the time with patients, physicians are required to complete paperwork and documentation following their appointment. Sometimes, documentation overlaps MA-patient periods or when no patients are in the clinic. The model assumes that if a patient is ready and waiting in exam rooms, the physician prioritizes seeing the patient rather than completing the documentation process. Finally, MAs escort patients to the check-out desk and leave the clinic. The model considered all these details to ensure accuracy in the system representation.

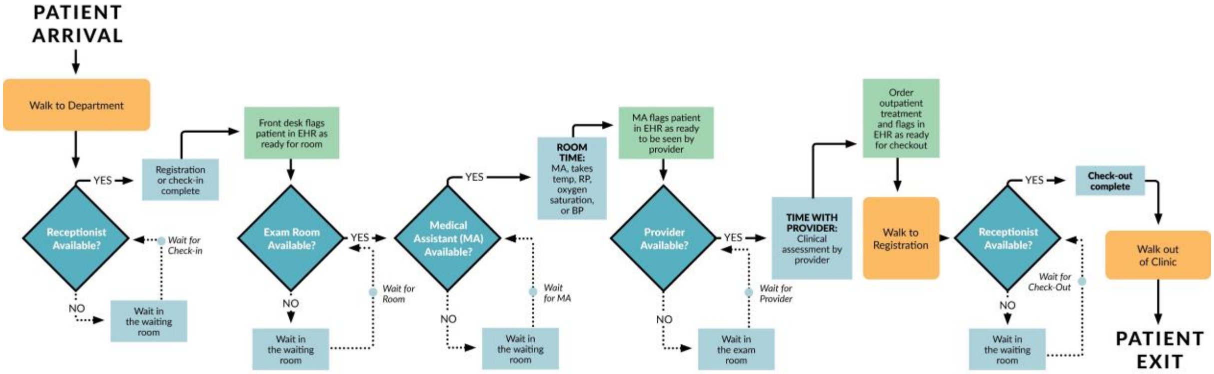

Fig. 3. Patient flow diagram for the pediatrics and PC departments
Source: Author (2023)

D. Model Validation

To verify the accuracy of the simulation model, we tracked progression and ensured logical precision. The model findings were presented to a team, including clinicians and managers, in several meeting sessions. Team members' insights and suggestions were accounted for in updating and adjusting the model. At the final meetings, the team agreed that the represented outputs were consistent with current departmental operations. To improve communication between the researcher and clinicians, we shared the animation of the simulated model that exhibits patient flows and utilization of rooms, staff, or equipment.

The study accomplished statistical validation of the model using two-sample t-tests that compared model milestone-to-milestone outputs to historical information. These milestones included: arrival-to-seen by the provider, room time, and arrival-to-exit (LOS). Findings showed no significant difference between the underlying means at 95% intervals. Thus, the simulation was assumed to represent the actual system accurately and employed as the foundation of the analysis and scenario comparisons.

III. RESULTS

A. Current State Analysis

The current state analysis evaluated if the new design and proposed staffing provide enough capacity for the current patient volumes. The current state model results showed that three primary care clinicians exhibit patient waiting for providers and exam rooms during maximum patient volume (See Figure 4). Further, the FlexSIM output suggested a high average percentage of provider utilization for PC 2 and PC 4 (M= 83% and M = 86%, respectively), thus resulting in longer durations of WFP outcomes for the patients of these two departments.

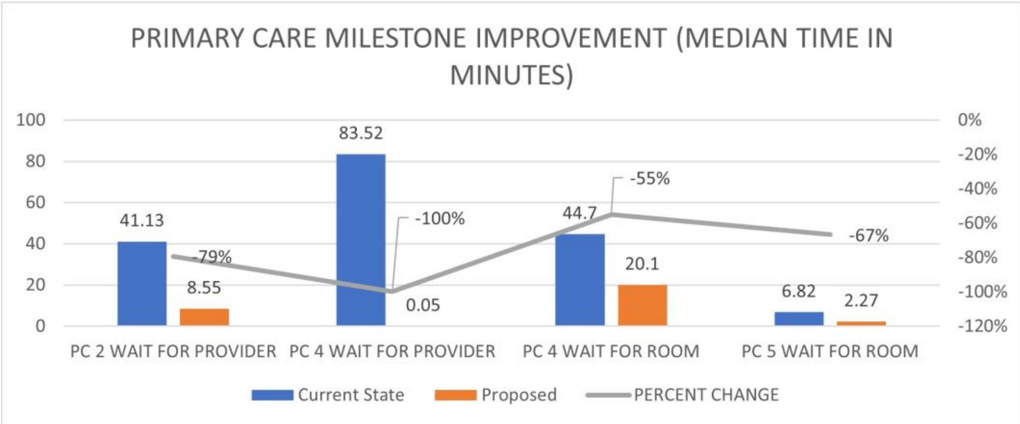

Fig. 4. Current and proposed milestone comparisons of patient wait times for providers or exam rooms
Source: Author (2023)

Figure 5 displays the average percentage of space utilization for the primary care department space resources. As we discussed earlier, PC 4 has a high exam room utilization rate during peak hours, resulting in patient wait times. The average exam room utilization for the pediatrics department was 24%, suggesting its capacity for resource-pooling strategies.

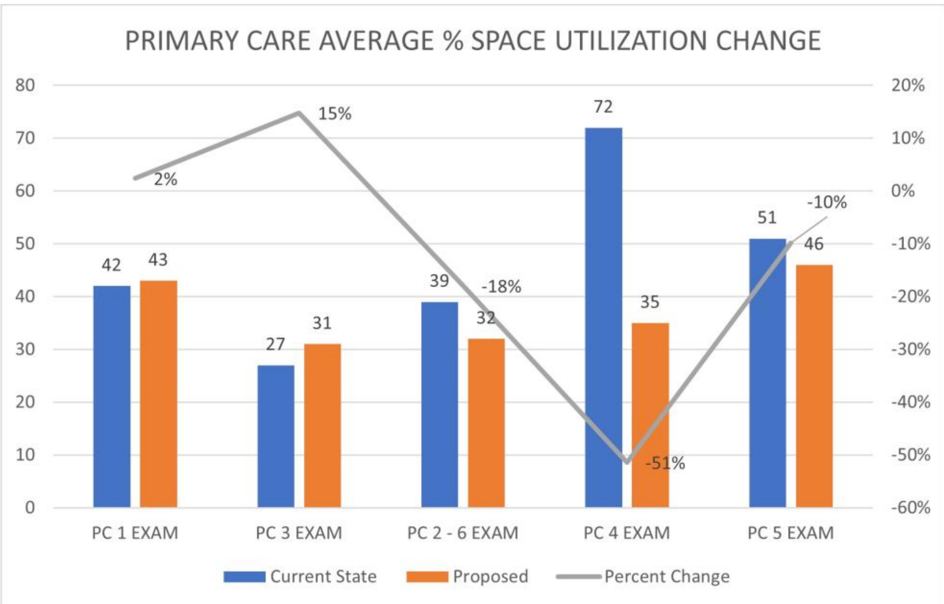

Fig. 5. PC department average percentage of space utilization comparison in the current and proposed scenario model (Source: Author (2023)).

We initially created the current state of the registration process in the DES for evaluating the second question. In the proposed layout, the planners had assigned each department a registration area where patients complete registration, check-in, and check-out. The red box in Figure 6 displays the multiple registration desks assigned to each department. The model calculated the outpatient clinic receptionist staff's average percentage of utilization per hour. Focusing on the primary care departments, the model showed an average staff utilization as PC2, PC3, and PC6 = 45%, PC 5 = 28, and PC4 = 17%. This finding implies that with the current decentralized registration setup, receptionists need to be more utilized, and the departments may benefit from staff pooling.

Fig. 6. The location of registration desks in the current multi-department floor plan
Source: Author (2023)

B. Proposed Solutions and Findings

To address the second question on the impact of a centralized registration system, we pooled the registration area for the primary care departments on the East and West sides of the building. The proposed model also reduced registration staff from 14 to 9 (sum for East and West locations). The decision to pool for only the primary care department stemmed from user group conversations across departments suggesting this implication would be a viable option. Staff from the other departments mentioned that merging the registration desks with other departments may be problematic for specific patient demographics or types. For example, staff from the neurology department mentioned the need for training and specialized conversations for dementia patients that would not be accomplished through a centralized registration system. Therefore, registration pooling was not explored for other departments as a viable option.

During the interviews, clinicians and administrative staff also perceived that primary care patients could benefit from utilizing kiosks for check-in, complete registration, or check-out. Further, we explored the possibility of including kiosks in the model. The simulation scenario included six kiosks on the West and two on the East side of the clinics, assuming that 20% of patients will use kiosks for check-in or registration. Figure 7 illustrates the proposed design changes in the primary clinic departments.

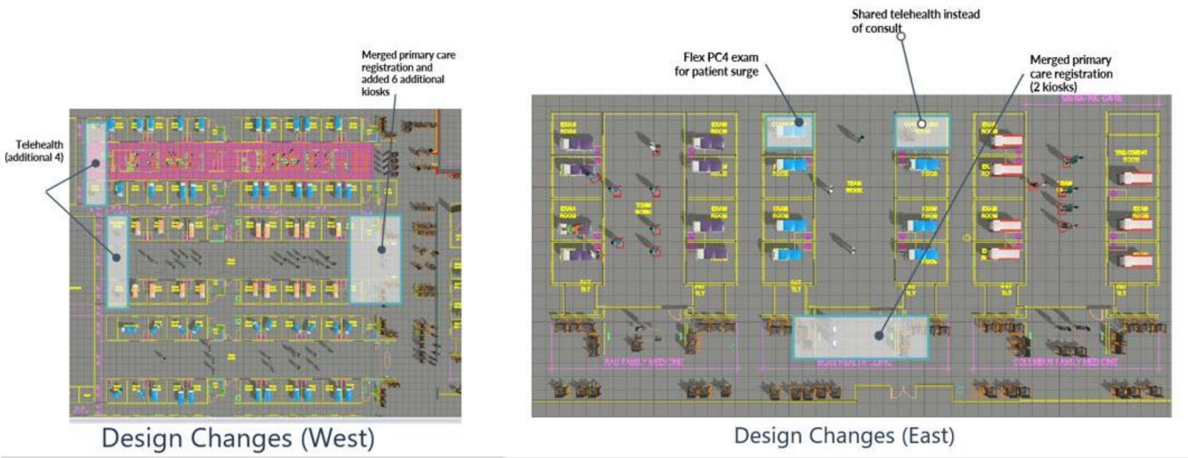

Fig. 7. Proposed changes for the West PC, pediatrics, and East PC departments
Source: Author (2023)

This registration pooling increased staff utilization. The average utilization for the current state registration staff was 31.8% and increased to 49.4%. Independent Samples T-Test analysis showed that pooling registration staff resources between the primary departments significantly increases the average percentage of utilization rates ($t = -3.244$, $df = 58$, $p = 0.002$). Further, by redirecting the patients to telehealth rooms, the PC5 patient wait for the room noticeably decreased by 10% ($P > 0.05$) (see Figure 40.

The third objective is to evaluate if some underutilized rooms were dedicated to other functions and how it impacts their utilization level. The current state simulation model showed that the pediatrics exam room utilization was underutilized. Thus, four of the exam rooms were converted to other functions. The proposed simulation model accounted for two of the pediatrics and three of the primary care exam rooms for telehealth services. In addition, two of the pediatric department exam rooms were converted into a dedicated pediatrics waiting space separated from the main concourse.

One of the consult rooms in PC4 was altered into a flex exam-consult room to accommodate the peak patient volume need for an additional exam room. The additional exam room substantially improved the median WFR for PC4 patients and the average percentage of exam room utilization. Since the number of observations for patient-wait in exam rooms was less than two for the proposed process, T-Test comparisons needed to be more attainable. Substituting pediatrics exam rooms for other functions somewhat increases exam room utilization from 24% to 29%, but this change was insignificant ($t = -0.872$, $df = 18$ $p = 0.395$). This finding shows how DES simulation can benefit designers for space planning function delegation.

To analyze the fourth question and based on the current state analysis on the wait for the provider outputs, the primary care staffing considered including an additional provider for PC2 and PC4 during peak volumes. Results suggest a significant decrease in median WFP for PC2 with an additional provider during maximum patient volume ($t = 6.87$, $df = 137$, $p < 0.001$, M (current) = 38.78, M (proposed)= 12.15). Adding an extra provider for PC4 during peak patient volume significantly decreased WFP durations ($t = 11.146$, $df = 50$, $p < 0.001$; M (current) = 67.50, M (proposed) =2.52).

IV. DISCUSSION

Renovation or new construction of outpatient clinics is an expensive, complex, and extensive task. Planners and architects of these facilities mainly focus on design aspects, safety codes, or building standards rather than efficiency outcomes (Arnolds & Gartner, 2018; Vahdat et al., 2018). However, the proposed layouts must develop policies to provide a satisfactory quality of care and optimized operations. Over the last 40 years, DES models have been growing in popularity and have been accepted by healthcare administrators as practical tools for resource allocations that improve patient flow and satisfaction (Cai & Jia, 2019; Fone et al., 2003; Mielczarek & Uziałko-Mydlikowska, 2012; Norouzzadeh et al., 2015; Rohleder et al., 2007; Swain, 2011).

DES facilitates decision-making and empowers healthcare planners by analyzing the impact of various feasible alternatives (Swain, 2011; Zamani, 2022; Zeigler et al., 2000). DES is particularly advantageous in determining the impact of planning or expanding healthcare centers by accounting for various resources, stakeholder needs, clinical rooms, and patient volume (Brailsford & Hilton, 2001; Cai & Jia, 2019; Mielczarek & Uziałko-Mydlikowska, 2012). The current study provides insight into the essential role of the DES modeling in identifying potential space or staff limitation n or underutilization in the future multi-department clinic. Future studies are recommended to explore opportunities and limitations of DES implementation for planning decisions across different healthcare facilities.

The findings from the current study provide a valuable perspective on the essential role of DES in evaluating outpatient healthcare systems' unpredictable and variable nature prior to final planning and schematic design finalization. In their study, Cai & Jia (2019) emphasize the importance of early engagement of DES in the planning and design phase. Aligned with these recommendations, the authors believe that one of the limitations of this study was the late involvement of the researcher in the DES study. This delay was due to a spontaneous decision during the planning stage, leading to proposing the DES as an evaluation tool; therefore, although the clients found the model results applicable and valuable, the recommendations needed to be implemented in actual reality. This finding aligns with Vázquez-Serrano et al. (2021) study that performed a literature review focused on DES modeling healthcare settings illustrating that less than 10% of DES recommendations are implemented for system performance improvement.

Resource allocation to determine staffing levels or physical environment resources for optimal use of the facility is the most prevalent application of DES (Mielczarek & Uziałko-Mydlikowska, 2012; Vahdat et al., 2018). Previous studies have employed DES to examine the advantages of pooling resources when designing outpatient facilities (al Hroub et al., 2019; Ciulla et al., 2018; Norouzzadeh et al., 2015; Vahdat et al., 2018; Vanberkel et al., 2012). For example, Rohleder et al. (2007) employed simulation modeling to show how consolidating smaller facilities into broader patient service center networks provides opportunities for pooling resources (such as exam rooms), reduces demand variability, improves resource utilization, and decreases patient waiting time. Norouzzadeh et al. (2015) found improved room utilization through the implication of "pod" models, where rooms are divided into two groups and shared among practitioners within each pod.

While the analysis of dedicated and pooled resources exists, minimal studies focus on the operational impact of pooled and dedicated registration spaces and staffing for multi-department clinics. Consistent with prior literature on the benefits of pooling resources (al Hroub et al., 2019; Santibáñez et al., 2009; Vahdat et al., 2019; Vanberkel et al., 2012), the findings from this study indicated that pooling registration desks and staffs in addition to kiosk integration were an effective strategy to improve space and staff utilization.

Kiosks have been recognized as a contemporary resource and economically sustainable solution to reduce efficiency and costs by improving staff allocations and efficient use of non-clinical staff (Belt, 2015; Mosher et al., 2020). Further, studies suggest that kiosks improve patient satisfaction (Belt, 2015; Mosher et al., 2020). For example, Mosher et al. (2020) found that after kiosk implementation in an academic orthopedic clinic, check-in durations were reduced by 60%, and patient satisfaction increased by 12%. However, satisfaction and successful kiosk usage may differ depending on patient demographics, age, literacy level, and socioeconomic classification (Mosher et al., 2020; Song et al., 2020), which aligns with the clinical staff interview findings in this study.

Evidence suggested the growth and increased utilization of telehealth outpatient services for non-emergent health issues that can be addressed virtually (Betancourt et al., 2020; Greiwe, 2022; Wosik et al., 2020). Therefore, it is essential for designers and planners of future outpatient facilities to dedicate spaces that are intentionally designed for telehealth services. These rooms need high-quality speaker systems, video cameras, colors, and monitors (Avis, 2020; Guilford-Blake, 2022). These design qualities ensure reliable and effective communication and protect patient privacy during telehealth visits (American Medical Association, 2020; Avis, 2020; Wosik et al., 2020).

The simulation was a powerful tool for converting several under-utilized exam rooms into a pooled telehealth resource that improved room utilization and exam room availability across departments. The intent was to accommodate future volume growth for telehealth demands in outpatient

clinics (Patel et al., 2021; Tresenriter et al., 2021; Wang et al., 2021). It also provided an opportunity for designers to create dedicated telehealth rooms. Future studies are recommended to explore different layouts and design recommendations for telehealth rooms within a multi-department outpatient clinic.

There is an extensive need for enhanced flexibility of resources in healthcare facilities to cope with the sudden influx of patient volumes (Khorram-Manesh, 2020; Łukasik & Porębska, 2022). In architecture, flexibility is described as the environment's ability to acclimate to spatial alterations in short, medium, or long periods (Brambilla et al., 2021; Buffoli et al., 2012; Capolongo et al., 2020; Łukasik & Porębska, 2022). In healthcare facilities, this adaptation corresponds to transitions in technology, patient flow, medical standards, or procedures (Brambilla et al., 2021; Capolongo et al., 2020; Łukasik & Porębska, 2022). The findings from the current study also suggest dedicating several flexible exam-consult rooms for patient treatment during high-volume patient flows in multi-department clinics as a design solution to reduce patient wait time.

Resource pooling provided an opportunity to suggest a dedicated pediatric waiting room space. Previous studies show that segregating the waiting areas for pediatric patients from adults creates playful learning experiences, offers a sense of security for children, encourages social interactions, and improves patient and family satisfaction (Leong et al., 2018; McLaughlan, 2018; McLaughlan et al., 2019). The DES scenario outcomes showed that such alterations did not substantially affect patient wait for exam rooms. Thus, the data-driven strategy provided an opportunity to suggest design alterations for creating a potential psycho-socially supportive pediatric waiting area without impacting revenue-generating spaces.

Aligning with prior literature (Cai & Jia, 2019; Vahdat et al., 2018, 2019), the current project showed that involving medical and management staff during the simulation development ensured that the model represents a realistic situation for the future clinic. Stakeholder involvement helped refine the system, create essential decision points, and improve their comprehension of the model to be implemented in real-life planning decisions. It also contributed to defining reasonable and achievable strategies for pooled resources across the departments. Besides, the graphic and video outputs of the simulation model improved communication and decision-making for stakeholders and facilitated model validation, which has been noted in prior studies (Cai & Jia, 2019; Vahdat et al., 2018, 2019; Zamani, 2022).

V. CONCLUSION

In conclusion, the findings from this study show that DES is an effective tool for analyzing the impact of alternative design strategies on operational outcomes to decrease waste and improve resource utilization. To fill the knowledge gap, this study addresses the minimally explored role of DES in an outpatient multi-department clinic facility. The complex interdependencies of the proposed multi-department clinic introduced high levels of uncertainties in staff and space resource management. Therefore, DES was an effective visual tool for designers to create data-driven design strategies to improve feasibility and decision-making for healthcare administrators and leadership. Involving stakeholders and clinicians during the DES model building was essential to defining reasonable and achievable strategies for pooled resources across the departments. It is further suggested to use Post Occupancy evaluations (POE), interviews, or surveys to understand behavioral and human factors and social, cultural, or behavioral aspects of the environment affecting process outcomes.

DES explored the impact of multiple variables, alternative solutions, and decisions on optimal scenarios. Our results present insight into the DES's effectiveness in evaluating resource pooling, space allocation, and space needs through a data-driven approach. This understanding is valuable, as improved resource allocation and streamlined operation is associated with cost reduction and enhanced patient and staff satisfaction. DES was beneficial in analyzing the effects of technology integration on patient wait times or efficient check-in or registration policies, such as kiosk implementation. The findings suggested opportunities that reduced wait time, accelerated check-in time, and improved space and staff utilization. It was found that a pooled registration or check-in staffing benefits departments of similar specialties, depending on patient type and needs. Further, DES suggested potential under-utilized spaces that were considered for alternative functions without resulting in adverse operational outcomes. The alternative space allocations provided dedicated spaces for flexible consult-exam rooms, telehealth rooms, and pediatric waiting areas.

In conclusion, the application of DES was an effective strategy to evaluate and communicate the impact of design alternatives on performance-driven outcomes and interdependencies. Emerging tools such as DES provide data for architecture and planning clients to make informed decisions, but they still need to be simplified and resource intensive. We invite a future where quantitative and qualitative solutions are considered from a single workflow and are more intuitive.

VI. LIMITATION

The findings of this study should be interpreted considering certain limitations. Firstly, the results may not be generalizable to other populations based on one case study. Each organization has its planning visions, patient volume, and process flows. However, the study successfully demonstrates the applicability of DES for planning decisions, room function dedication, or resource optimization. Secondly, some departments indicated higher telemedicine appointments due to the increasing demands for virtual consultation and wellness visits during the COVID-19 period. This variation presented a drawback in the trust of simulation findings for end-users and decision-makers as they were skeptical if the given patient volume realistically reflected future volumes and spatial needs. Further, the need for telehealth rooms may have been impacted by this rising demand for telehealth appointments.

The successful application of kiosks and the percentage of patients using the kiosks for check-in and check-out were based on staff perceptions of patient acceptance of this modern technology. However, this perception may not represent the acceptance of the actual patient population. With proper education and assistance, kiosks may play a more pivotal role in outpatient clinic patient flow and its potential benefits for clinic flow improvements. Mock-ups or patient survey data improve this interpretation and further explore this opportunity for patient flow management in model refinement.

Lastly, during the interviews, clinicians described how they sometimes forgot to record the appointment details in the electronic medical record system. Consequently, data validation and interpretation were a significant challenge, as many of the historical patient data needed further evaluation and outlier removal. Aligning with prior studies, we found a substantial amount of front-end data gathering, cleaning, and interpretation linked to cost and time (Cai & Jia, 2019). As a result, we emphasize the significance of staff training to document patient flow accurately in the EMR database for future process improvement analysis and readily available data.

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